

tion of iodinated contrast materials. Concurrent peripheral MRI venography can also be done to evaluate for the presence of deep venous thrombi. The ability to evaluate for both pulmonary embolism and deep venous thrombosis in less than an hour makes MRI an attractive modality in the diagnosis of thromboembolic disease.

Unfortunately, the hardware and software necessary to produce clinically useful images of the pulmonary vascular tree are not yet widely available or widely used. Spiral CT is more widely available and can better evaluate the lung parenchyma and mediastinum as well as the pulmonary vasculature. Therefore, it can detect other disease processes that could mimic pulmonary embolism on ventilation-perfusion scans.

MARK BALDECK, DDS, MD
LOREN KETAI, MD
Albuquerque, New Mexico

REFERENCES

Gefter WB, Hatabu H, Halland GA, et al: Pulmonary thromboembolism: Recent developments in diagnosis with CT and MR imaging. *Radiology* 1995; 197:561-574

Matsumoto AH, Tegtmeier CJ: Contemporary diagnostic approaches to acute pulmonary emboli. *Radiol Clin North Am* 1995; 33:167-183

Touliopoulos P, Costello P: Helical (spiral) CT of the thorax. *Radiol Clin North Am* 1995; 33:843-861

Magnetic Resonance Imaging of Radiographically Occult Bony Trauma

SUBSTANTIAL BONY INJURIES related to acute trauma or repetitive stress may not be detected on plain radiographs. Magnetic resonance imaging (MRI) has proved to be a powerful tool to assess these radiographically occult injuries, primarily because of its ability to show associated changes in the underlying marrow.

Trabecular bone is commonly injured during athletic activities. "Bone bruises" may be the sole cause for a patient's symptoms, and occasionally may result in adverse long-term sequelae if not treated appropriately. Plain radiographs are notoriously insensitive for detecting trabecular injuries because the overlying cortex is often intact. Because of its exquisite soft tissue contrast, MRI is able to depict the associated marrow hemorrhage or edema. Its ability to display concomitant soft tissue injuries is one advantage of this technique compared with radionuclide bone scanning.

Nondisplaced fractures may also be missed on plain films. Occult hip fractures in elderly patients present a particular diagnostic challenge because a radionuclide bone scan may be normal for the first few days after injury in these patients. Again, because of its sensitivity for detecting associated marrow changes, MRI can rapidly detect occult fractures with a high degree of accuracy. Similarly, a normal MRI virtually excludes serious bony injury, thereby allowing efficient patient evaluation. If a limited protocol is used, this technique can be cost-competitive with other modalities such as a radionuclide bone scan, often with greater specificity.

Stress fractures are becoming more common in our increasingly active society. Rapid, accurate diagnosis is

important because clinical assessment can be difficult, and biopsy in the early stages of stress injury may result in a mistaken diagnosis of neoplasm due to the presence of immature cells related to the reparative process. Plain radiographs are insensitive in these early stages, but MRI is able to detect the associated marrow changes and sometimes a distinct fracture line as well, before the typical periosteal reaction or fracture is detectable on plain films. As such, it is a useful diagnostic adjunct when a radionuclide bone scan is indeterminate.

Although the use of MRI has come under scrutiny because of current economic forces, it may prove to be the most cost-effective means for arriving at a rapid and accurate diagnosis in a patient with a radiographically occult bony injury.

MARK ANDERSON, MD
Davis, California

REFERENCES

Anderson MW, Greenspan AG: State of the art: Stress fractures. *Radiology* 1996; 199:1-12

Quinn SF, McCarthy JL: Prospective evaluation of patients with suspected hip fracture and indeterminate radiographs: Use of T1-weighted MR images. *Radiology* 1993; 187:469-471

Vellet AD, Marks PH, Fowler PJ, Munro TG: Occult posttraumatic osteochondral lesions of the knee: Prevalence, classification, and short-term sequelae evaluated with MR imaging. *Radiology* 1991; 178:271-276

Magnetic Resonance Imaging of the Breast

MAGNETIC RESONANCE (MR) mammography has been under technical and clinical evaluation for more than 14 years. Although initial data clearly indicate the suitability of MR imaging of the female breast, the use of MR mammography in evaluating breast disease has yet to be fully realized. Current applications are limited to the diagnosis of cancer in selected patients, the staging of known breast cancer, and the evaluation of silicone implant integrity.

Magnetic resonance mammography has undergone extensive evaluation as a noninvasive means for distinguishing between benign and malignant breast lesions identified by conventional mammography. Among the currently available imaging modalities—mammography, sonography, thermography, and computed tomography (CT)—only the use of mammography has been able to show a substantial reduction in the mortality associated with breast cancer, particularly for women older than 50 years. By using repetitive MR imaging of the same slices before and at short intervals after the administration of a contrast medium, known as "dynamic MR mammography," an 88% to 100% sensitivity in differentiating benign from malignant lesions has been reported. In the absence of contrast enhancement, a carcinoma can be excluded with a high degree of certainty.

The greatest enthusiasm for MR mammography in evaluating breast disease is as a screening tool for the large number of women with mammographically dense breasts and a relatively increased risk for breast cancer due to a strong family history of the disease.

Mammographically dense breasts make the exclusion of small tumors difficult. This is particularly worrisome in high-risk patients. The characteristic changes of dynamic MR mammography are capable of discriminating these lesions. Moreover, the characteristic changes are known to apply only to active tumor regions and not to necrotic or fibrotic regions.

Magnetic resonance imaging of the breast in patients with silicone prostheses has proved to be highly accurate in identifying the common complications associated with the implants and in characterizing concurrent disease. A silicone breast implant has a uniform signal intensity that is easily distinguished from pectoralis muscle and breast parenchyma. This permits obvious positioning of the breast implant in relation to adjacent anatomic structures. Ruptured and intact implants are immediately differentiated with a high degree of specificity using MR mammography. Moreover, when implants are found to be ruptured, MR mammography is able to demonstrate whether the silicone material remains within the fibrous surgical capsule or has extravasated into surrounding tissue. In patients with trauma, MR mammography can distinguish a hematoma in the breast parenchyma from silicone that has extravasated into the surrounding tissues.

Although there is a need to identify in which women there is a high risk of breast cancer developing, the widespread use of MR mammography as a screening tool for the disease is not economically feasible because of its high cost. Cost analysis indicates that MR mammography is useful as a diagnostic adjunct to conventional breast imaging modalities that are difficult to interpret due to mammographically dense breasts, surgical scarring, or the presence of silicone implants.

ROBERT ROSENBERG, MD
LAURENCE D. CAMBRON, PhD, MD
MICHAEL R. WILLIAMSON, MD
Albuquerque, New Mexico

REFERENCES

- Adler DD, Wahl RL: New methods for imaging the breast: Techniques, findings, and potential. *AJR Am J Roentgenol* 1995; 164:19-30
- Harms SE, Flamig DP, Evans WP, Harries SA, Brown S: MR imaging of the breast: Current status and future potential. *AJR Am J Roentgenol* 1994; 163:1039-1047
- Stelling CB: MR Imaging of the breast for cancer evaluation: Current status and future directions. *Radiol Clin North Am* 1995; 33:1187-1204

Radiosurgery

EACH YEAR MORE THAN 100,000 people in the United States are diagnosed with a benign or malignant brain neoplasm. Recent media reports focusing on radiosurgery, a relatively new treatment designed to halt neoplastic growth in the central nervous system, have raised expectations for cure or improved local control over standard treatments. Although not all patients are candidates for radiosurgery, an understanding of its mechanics, indications, selection factors, results, and cost is helpful when responding to patient inquiries or referring patients to radiosurgical facilities.

Radiosurgery, a noninvasive irradiation technique using stereotactic methods, is performed with narrow

intersecting beams of one of three types of penetrating radiation: gamma rays produced by the decay of cobalt 60 in a Gamma knife (a specialized apparatus whose sole function is radiosurgery), x-rays produced in standard linear accelerators that have been modified to do radiosurgery, and charged particles such as protons or other ions produced by a cyclotron or synchrotron. No radiosurgical method currently has a clinically demonstrable advantage over another. Although there are a large number of linear accelerators in the United States, most patients are treated on Gamma knife machines. In each case, the intent is to produce cell death or blood vessel thrombosis of targeted tissue within a small, well-defined volume. Accurate targeting is required because the intense radiobiologic effects produced by a single high dose of radiation could result in radionecrosis of normal central nervous system (CNS) tissue. With current technology and commonly used doses, the risk of radionecrosis is often claimed to be less than 5% in many patients, but approaches 20% in patients with malignant gliomas.

The radiosurgical procedure involves a sequence of tasks: temporarily attaching a stereotactic frame to the patient's head, obtaining stereotactic radiologic images of the target and surrounding structures, delineating the target contour on the images, planning treatment by interactively displaying dose contours on computer monitor views of the images, positioning the frame with respect to the radiation beams, and irradiating the target in a single session. The entire process takes a day to do and requires a radiation oncologist, a neurosurgeon, a radiologist, a physicist, and a nurse; in some cases, such as those of children, an anesthesiologist may also be required. Patients are comfortable throughout the procedure, and most return to baseline activity in a day or two.

About 50,000 patients worldwide have been treated with radiosurgery, mostly in the past five years. About a third of these had arteriovenous malformations, a third had benign tumors (such as acoustic neuroma and meningioma), and a third had malignant tumors (glioblastoma, astrocytoma, and metastatic tumors). Clinical reports show that patients selected for treatment should have good neurologic function and a radiologically well-defined target. Most important, the target should be small—usually less than a few centimeters in maximum dimension. For larger targets, it may be impossible to select a dose that provides both a high chance for cure and a low risk for complications. This inverse relationship of dose and volume is supported by clinical experience and radiobiologic theory. Because the target is small, previous irradiation is not a contraindication to radiosurgery.

Numerous retrospective studies have shown that about 35% of arteriovenous malformations selected for radiosurgery are no longer angiographically visible within a year and 85% within two years. Permanent neurologic complications attributable to radiosurgery occur in fewer than 5% of patients treated by experienced teams. These complications may take months or even years to develop, however. Angiographic resolution of the arteriovenous malformation after radiosurgery appears to be equivalent